

Research - Kasteran* — Visual Syntax and Rune-Based Languages

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Abstract

Rune-based programming languages—which employ symbolic glyphs (runes) rather than alphabetic keywords—represent a radical departure from conventional syntax design. Drawing inspiration from Urbit’s Hoon, APL, and assembly language mnemonics, Kasteran* adopts a hybrid approach: a core syntax of symbolic operators for fundamental operations, with extensible literate syntax for domain-specific abstractions. This document examines the cognitive, linguistic, and engineering implications of rune-based syntax and its application to systems programming.

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Abstract

Rune-based programming languages—which employ symbolic glyphs (runes) rather than alphabetic keywords—represent a radical departure from conventional syntax design. Drawing inspiration from Urbit’s Hoon, APL, and assembly language mnemonics, Kasteran* adopts a hybrid approach: a core syntax of symbolic operators for fundamental operations, with extensible literate syntax for domain-specific abstractions. This document examines the cognitive, linguistic, and engineering implications of rune-based syntax and its application to systems programming.

1. Introduction

The overwhelming majority of programming languages use alphabetic keywords drawn from natural language (e.g., `if`, `while`, `return`, `class`). Rune-based languages reject this convention, using symbolic tokens to encode program structure and semantics. Proponents argue that symbolic syntax reduces syntactic noise, enables more concise expression, and allows the language to be read as a structured visual pattern rather than as linear text. Critics counter that rune-based syntax increases cognitive load, harms learnability, and impedes accessibility. Kasteran* explores a middle path: a core rune vocabulary for control flow and type operations, combined with user-definable surface syntax through a macro system.

2. Historical Background

The oldest rune-based language still in active use is APL (A Programming Language), developed by Kenneth E. Iverson in the 1960s. APL’s notation was originally designed as a mathematical notation for teaching array operations (Iverson 1). Its implementation used a custom character

set requiring specialized terminals; modern APL systems use Unicode. The language employs over 80 distinct glyphs, each representing a primitive array operation. Research on APL’s cognitive dimensions suggests that experienced users achieve remarkable productivity for array-intensive tasks, but the language’s extreme concision poses significant barriers to novice programmers (Hui 1).

Urbit’s Hoon language takes rune-based design to its logical extreme. Every syntactic construct in Hoon is represented by a two-character rune—digraphs like `|=` (function definition), `?:` (conditional), and `:-` (cell construction). Hoon has no reserved words; all syntax is composed from a vocabulary of approximately 100 runes (Yarvin 1). The design philosophy holds that by eliminating keywords, Hoon becomes a “regular” language where any sequence of tokens can be parsed unambiguously. Recent analyses of Hoon’s syntactic design highlight trade-offs between regularity and readability (Lo 1).

Assembly language mnemonics represent a third tradition in symbolic syntax. While not strictly rune-based, assembly’s use of abbreviated opcodes (`mov`, `jmp`, `push`, `pop`) and register names (`eax`, `rsp`) creates a compact, visually distinctive notation. The RISC philosophy further reduced instruction mnemonics to minimal symbolic forms, emphasizing that each symbol should correspond to a single primitive operation (Patterson and Ditzel 1).

The cognitive science literature on programming language syntax suggests that visual pattern recognition plays a significant role in how programmers read and comprehend code. Blackwell’s Cognitive Dimensions framework identifies “closeness of mapping” between the problem domain and the notation as a key factor in usability (Blackwell and Green 1). For rune-based notations, the opacity of individual symbols may reduce closeness of mapping, but the visual distinctiveness of rune patterns may improve “secondary notation”—the use of layout and visual cues to convey meaning.

3. Technical Analysis

Kasteran*’s rune vocabulary is organized into functional categories. Each rune is a Unicode code-point or digraph chosen for visual mnemonic value. The control flow runes include: `→` (function arrow), `(` (match arm), `λ` (lambda), `⌈` (optional path), `⌋` (effect handler). Type runes include: `·` (type application), `⌈` (boxed type), `⌋` (nullable type), `⌋` (lifetime parameter). Operation runes include: `(swap)`, `(copy)`, `(move)`, `(composition)`, `(merge)`, `(product)`, `(choice)`.

The parser transforms this rune stream into an AST through a Pratt parser variant that assigns precedence and fixity to each rune. Runes are classified by arity (nullary, unary, binary, trinary) and associativity (prefix, infix, postfix, circumfix). The syntactic regularity ensures that every rune application forms a well-delimited syntactic subtree, which disallows the ambiguity that plagued early rune-based languages.

Kasteran* supports a literate syntax extension mechanism: the macro system allows users to define named syntax trees that expand to rune sequences. A literate syntax definition takes the form:

```
syntax `if ($cond) { $then } else { $else }`
  ( $cond , →{ $then } , →{ $else } )
```

This mechanism bridges the gap between symbolic core syntax and human-readable surface syntax. Libraries can define domain-specific syntaxes with arbitrary keywords and delimiters, which expand to core rune operations during parsing. The expansion is purely syntactic; type checking and

optimization operate on the desugared form, ensuring that syntax extensions impose no runtime overhead.

The cognitive implications of rune-based syntax have been studied experimentally. Research by Erlikh demonstrates that symbolic languages can be read more quickly by experienced programmers due to the visual distinctiveness of runes, but at the cost of increased time to achieve proficiency (Erlikh 1). The Kasteran* design addresses learnability through graduated disclosure: beginners can write entirely in literate syntax, gradually learning runes as they expand syntax macros. The IDE provides rune tooltips and a visual desugaring mode that shows the rune expansion of any literate syntax fragment.

4. Current State of the Art

Modern rune-based languages are rare but influential. The J language (a successor to APL) continues to find use in financial modeling and scientific computing, with an active community exploring tacit (point-free) programming styles (Burke 1). Uiua is a contemporary stack-based array language using Unicode glyphs, drawing on APL and BQN but with a modern toolchain and a focus on visual programming. The BQN language by dzaima further refines APL’s notation with cleaner glyph semantics and improved Unicode support.

In the systems programming space, rune-based design remains virtually unexplored. Kasteran* represents the first attempt to combine rune syntax with memory safety guarantees, linear types, and a borrow checker. The challenge lies in making symbolic notation carry the information density required for type annotations, lifetime specifications, and capability tracking without overwhelming the programmer.

5. Relevance to Kasteran*

The rune syntax of Kasteran* serves several design goals. First, it makes the language visually parseable: the structure of a Kasteran* program can be understood from whitespace and rune patterns alone, without reading specific names. This supports code review and rapid scanning. Second, the finite vocabulary of runes ensures that every syntactic form has a unique canonical representation, simplifying tooling (formatting, refactoring, and analysis). Third, the literate syntax system enables domain-specific languages to feel like first-class extensions of the core language.

The choice of specific runes was informed by semiotic analysis: each rune’s shape is intended to evoke its meaning. The arrow $\rightarrow$ for functions follows mathematical convention. The diamond for optionality evokes branching or choice. The star $\star$ for lifetimes suggests boundedness. These mappings are not logically necessary—any arbitrary glyph could serve—but they reduce cognitive load by leveraging pre-existing visual associations.

6. Future Directions

The future of rune-based syntax depends on tooling and accessibility. Screen readers and braille displays struggle with symbolic notation, and Kasteran* must provide accessibility alternatives—nav-mode descriptions, speech-friendly textual aliases, and high-contrast themes. Internationalization of rune semantics (are runes culturally neutral?) remains an open question; research on APL adoption in non-English-speaking contexts suggests that symbolic languages reduce the language barrier but may increase the professional barrier due to specialized training requirements (Falkoff and Iverson 1).

Another frontier is the interactive and visual programming of rune syntax. Could Kasteran* programs be edited by manipulating rune structures directly, analogous to how structure editors manipulate ASTs? The visual regularity of runes makes them suitable for such representation, and prototype structure editors for APL-like languages demonstrate the feasibility of this approach.

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